8 ATTACHMENT IV — BLIP RASTER SYSTEM AIP

Revision	Affected Pages	Effective Date
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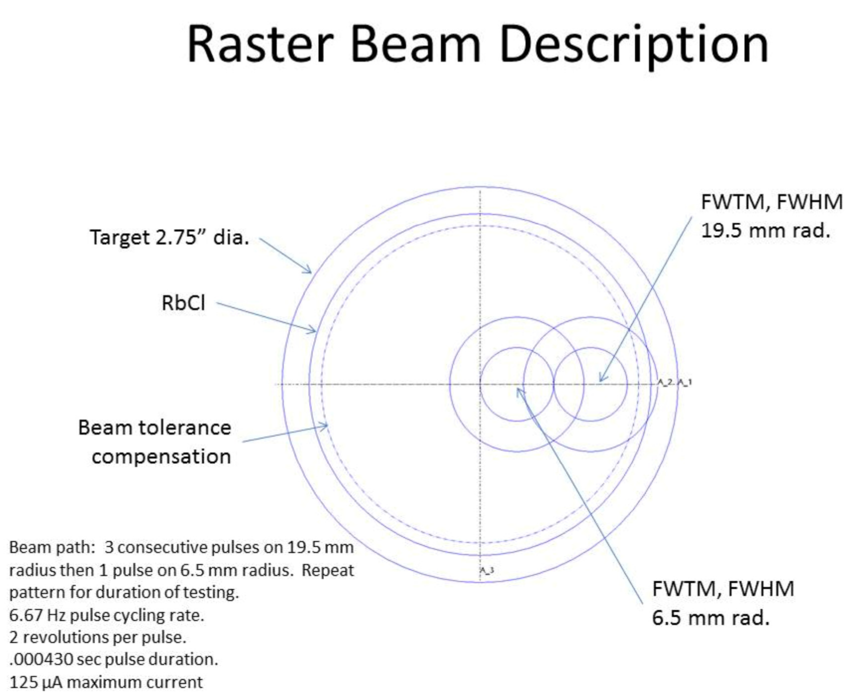
Project Description

The two most important isotopes produced at Brookhaven Linac Isotope Producer (BLIP) are Sr-82 and Ge-68, and demand currently exceeds our capacity. All else staying constant, increased beam current directly makes more product. Efforts to improve supply with increased current have been difficult. The Linac has succeeded in increasing the maximum beam current to BLIP to 125 µA and an average beam current of 110 µA has been achieved. The beam is pulsed and the instantaneous beam current can be as high as 43 mA. Combined with a sharply peaked Gaussian-shaped beam intensity profile this creates very high power density at the beam spot center (>4 kW/cm^2) and has caused target reliability and lifetime issues due to overheating, as well as somewhat erratic isotope yields. The short term response has been to limit Linac average current to no more than 105 µA. There is a better way. We propose to implement the design and installation of a beam raster system in BLIP with a rapid (5 kHz) scan frequency. Three consecutive beam pulses will be rotated in a circle of diameter 19.5mm radius, then one beam pulse will be rotated in a circle of diameter 6.5mm radius. This pattern will be repeated so that a nearly uniform beam intensity profile can be achieved. In this manner the beam will complete 2.25 rotations per beam pulse of 450 µs length and the power density is reduced by at least a factor of four. This will increase isotope yield and sharply reduce target fatigue.



Sr-82 is created by irradiating RbCl pressed pellet targets. RbCl has poor thermal conductivity, and with the existing fixed Gaussian beam spot the salt melts only in the beam strike area. Upon melting the RbCl expands 21% and moves outward, refreezing into void space on the target's periphery, and reducing the amount of RbCl remaining in the irradiation zone by an estimated 10%. This effect also shifts the proton energy on downstream targets higher than optimum leading to reduced and variable Sr-82 yield. The net impact on yield is as much as 20%. The raster parameters, 5 kHz sweep with dual radius, are driven by the thermal properties of RbCl. In addition the raster will minimize material creep as most of the target will be consistently molten, but with lower overall temperatures than at present. The lower average salt temperatures can, in principle, allow safe increases in beam current up to 240 μA, enabling target survival if a future project to double the average Linac beam current is approved and implemented. This compares favorably to the present maximum average beam current of 250 μA at the Isotope Production Facility at LANL where a raster system has already been implemented.

By spreading out the power density, a raster system will be beneficial for all targets by improving reliability. In 2011 and 2012 the Ge-68 target failure rate due to target leaks at high temperature was an unacceptable 50%. The program costs for replacement fabrication were approximately $65K, and the lost potential revenue was several times larger. To assure better target survivability, in 2013 the beam current incident on this Ga metal target has been limited to only 75 μA, thus reducing yield by 30%. By decreasing peak temperature by an estimated 200^{o}C with the raster, these targets will be able to survive at higher beam current.

The raster implementation will require rapid cycling magnets and power supplies to continuously move the beam spot. Diagnostic devices in the BLIP beam line that enable measuring the actual beam spot profile, both for initial device tuning and commissioning, and for routine monitoring, do not exist but are required. The needed devices include a laser profile monitor, beam position monitor, and a plunging multiwire device. An interlock system to detect raster failure is also essential. If the smaller beam spot were to stop moving target destruction could be rapid. In addition, existing beam current monitors in the beam line have become erratic due to age (41 years) and radiation damage and must be replaced. Beam intensity on target is critical information for the production program to predict radioisotope quantity, and for research projects to measure nuclear reaction cross sections of desired radioisotopes.

Return on investment

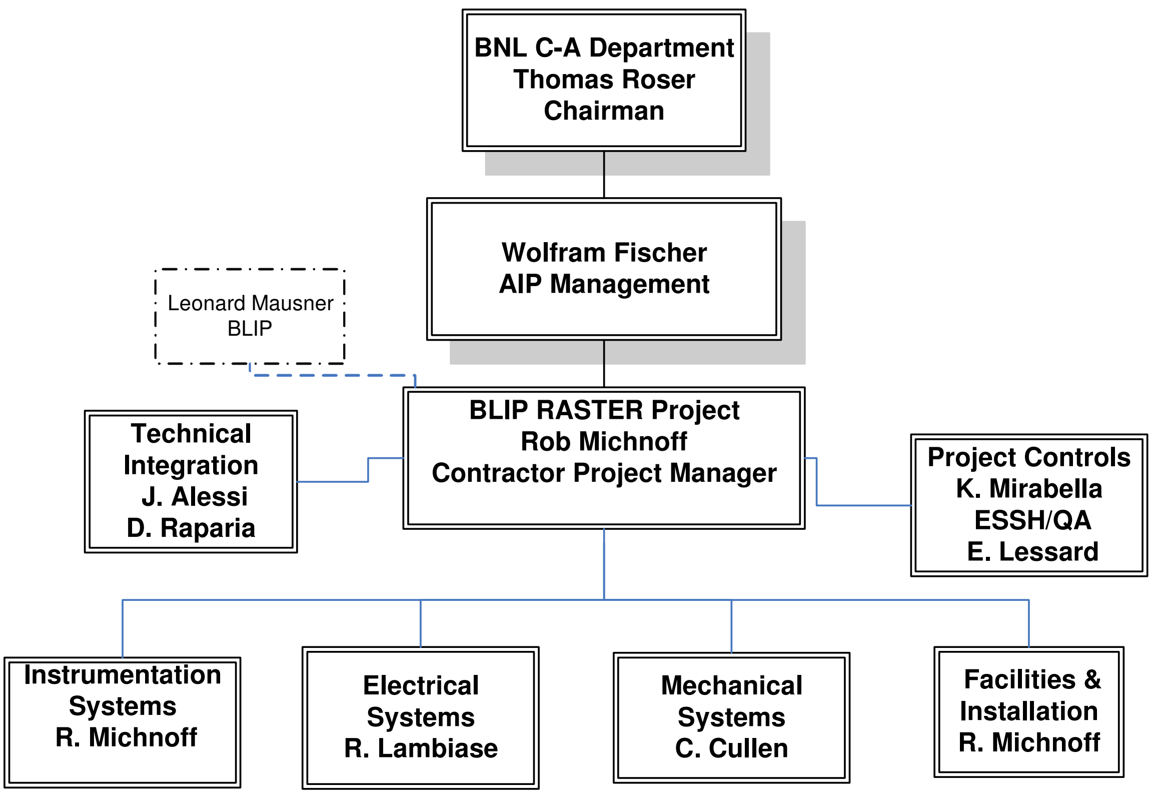
In 2012 and 2013 each year two batches of Sr-82 were lost due to target failure, representing a fabrication replacement cost of $32K. In addition since these targets failed after days or weeks in beam, there is the cost of the wasted beam time, approximately $50-100K per run or up to $200K per year and potential lost sales revenue. In addition an increase in Sr-82 yield of 20% with the raster represents additional potential revenue. Thus the beam raster project prevents target loss, improves target yield, and allows full Linac current on target. It is estimated that the return on investment can be realized in three years or less.

Estimated/potential impact on annual operating funds

This topic will be addressed when the Reporting Milestone "Decision on Radiation-hardened vs. periodic replacement" is complete. Until then the only impact to operating funds is the savings due to fewer failed targets, which is included in the ROI calculation above.

Project Management

The BLIP Raster system is funded as an Accelerator Improvement Project. Federal Program Manager for the BLIP Raster system project is Marc Garland and the Contractor Project Manager at BNL is Rob Michnoff. The project organization chart below provides additional detail.



Technical Scope and Deliverables

The project scope is to design, fabricate and install and commission the BLIP Raster system with the following components:

Raster System components include:

- 1 raster magnet
- 2 raster magnet power supplies (X and Y) and associated electronics
- 2 plunging harps and associated electronics
- 1 laser profile monitor and associated electronics
- 1 dual plane beam position monitor and associated electronics
- 2 beam current transformers and associated electronics
- controls equipment
- beam interlock system

A table of early and enhanced performance for each of the instrumentation systems is provided as an attachment to this document.

The key performance parameters (KPPs) that define successful completion of the project are:

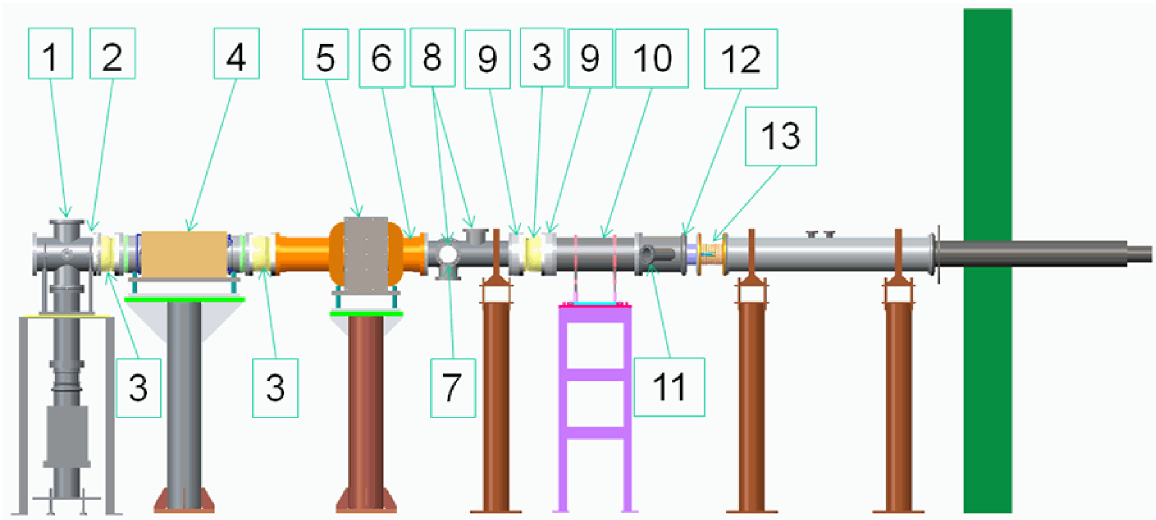
The Raster System is installed at BLIP and rastering and control of the beam is confirmed by the following key performance parameters:

- The raster magnets, power supply and associated beamline vacuum components and electronic equipment are installed. This includes components in the tunnel as well as in the BLIP control room.
- The beam is modulated horizontally and vertically to produce 5 kHz circular rastering of the beam with a fixed radius on the BLIP target.
- The average beam current is limited to 125 µA, the current that is currently used for non-rastered operation in order to provide additional safety against target damage.

The ultimate performance parameters (UPPs) are:

- The circular rastering of the beam will be configurable to occur at 2 different radii. The anticipated operation is to raster the beam at a radius of 19.5 mm for 3 consecutive 450 µs long pulses (2.25 rotations per pulse), then raster the beam at a radius of 6.5 mm for one pulse, and repeat the pattern.
- A beam interlock system that allows for an average beam current of 140 µA.

BLIP Raster system layout



Devices in the new BLIP beam line in order from upstream to downstream. The length from the upstream start to the existing beryllium window is 152.4" (3.87 m).

1. plunging harp
2. 6.5" collimator
3. aluminum bellows (3x)
4. raster magnet
5. steering magnet (existing)
6. 4.0" collimator
7. plunging harp (opposite side)
8. laser profile monitor
9. beam current transformers (2x)
10. beam position monitor
11. viewport and electron suppressor
12. beryllium window (existing)
13. aluminum bellows (existing)

BLIP Raster Magnet

The raster system contains a steering magnet in the beam line 6 meters upstream of the target station. The steering magnet is constructed with two copper conductor coil assemblies mounted on a single high frequency ferrite core. The two conductor coils permit simultaneous horizontal and vertical beam steering to create the desired circular beam path on the target. The steering magnet is placed external to a ceramic beam tube.

A ceramic tube was selected to eliminate eddy current losses and magnetic field distortion.
Two sets of cables will transport the sinusoids from raster power supplies located in service areas to the raster magnet. A metal enclosure around the raster magnet is required to minimize the electromagnetic interference to surrounding equipment and sensitive instrumentation.
Brookhaven will design and fabricate the coils, magnet, enclosures, and support structures.

BLIP Raster Power Supplies

The BLIP Raster power supplies are two identical sine wave sources, synchronized to maintain a 90° phase difference. The power supply equipment will be in a service building away from the high radiation beam line area. Two supplies will produce sine waves with a frequency of 5 kHz and a peak current of 318 Amps to drive the raster magnet coils.
BNL will design, develop, and fabricate the power supplies and design their auxiliary subsystems and PLC based control and status monitoring subsystems. All subsystems will be assembled together to form a complete raster power supply system.

Laser Beam-Profile Monitor

The beam profiles need to be monitored in the beam line between the rastering system and the BLIP window. Experience has shown that wire scanners and harps have limited lifetimes in the intense BLIP beam. With the larger average diameter of the beam created by the rastering, wire lifetimes are expected to be longer, however we estimates lifetimes shorter than a single beam run.
Since 2000, BNL has built five beam-profile monitors for H^- beams based on photo-neutralization by Nd:YAG lasers. The H^- ion is a bound state of one proton and two electrons with no excited states. The binding energy of the outer electron is 0.75 eV and an H^- ion can be neutralized by a photon with energy above 0.75 eV (λ < 1.67 mm). Since the detached electron is boosted into an energy continuum, the cross section vs. photon wavelength is a broad curve with a maximum at λ = 930 nm (E_γ = 1.3 eV). Profiles are obtained by scanning a laser beam across the H^- beam and recording the laser-stripped electron current vs. laser position.
All of the current devices use a Q-switched Nd:YAG laser. These lasers are limited to firing a single 10 ns long pulse at repetition rates <20 Hz, which yields only one measurement per linac cycle. A 45° scanning mirror moves between pulses and a profile is built up in 10-50 cycles. If such a device is built for a raster beam system many measurements will be required at each mirror location to average out the beam movement.
For the BLIP application a better approach is to use an Ytterbium pulsed fiber laser such as the Quantel Ylia M20 which has been tested at BNL. These are compact and inexpensive industrial lasers that are built to operate remotely. They are air-cooled and require no maintenance. This laser puts out 20 W at the optimum wavelength for this application in 100 ns pulses at a repetition rate of 20-100 kHz. With this approach, data will be collected continuously over the linac cycle at 10-50 μs intervals. The sum of all the collected pulses at each mirror position will represent the average beam signal at the laser position and the rastering motion will be evident in the modulation of the collected

pulses during the linac cycle. This sensitivity to the beam motion is a possible signal for a rastering interlock.

Plunging Multiwire Profile Monitors

Two semi-destructive plunging multiwires (harps) will be installed at the locations shown in the drawing to measure transverse horizontal and vertical beam profiles at low beam power.

A pneumatic actuator with two 32 x 32 wire harp heads can be provided by Princeton Scientific Corp. and will be mounted to a CF cross. The design of this beam line device is similar to many others in the Collider-Accelerator department. The 100 μm diameter harp wires are made of a tungsten/rhenium alloy and have a very high melting point. Each harp wire is spring mounted to allow for thermal expansion. The design is such that the wires will always be held straight during the measurement process. Wire heating temperature simulations were done by P. Thieberger using existing and future planned BLIP operating scenarios. The tungsten melting point is not reached, but the temperature excursions are relevant for thermo-mechanical fatigue failures. The expected transverse beam diameter is 5 mm FWHM and 10 mm FW at the base.

Each harp will have long signal cables feeding signal processing electronics in the service building. The electronics will consist of a Euro-chassis that houses eight 8-ch integrator modules. A nearby VME chassis will provide digitizers, timing and a digital I/O interface.

Beam Position Monitor

The purpose of the beam position monitor (BPM) is to measure the horizontal and vertical transverse positions of the beam. One BPM will be installed in the BLIP beam line and will be located downstream of the raster magnet.

A custom BPM will be designed to provide proper matching for the Linac beam parameters in the BLIP beamline - a 450 μs long pulse with repetition rate of 6.67 Hz. Since the beam is expected to be mostly debunched in the BLIP beamline, the 200 MHz RF structure is not expected to be present in the signal.

Backscattering of electrons from the Beryllium window into the BPM beam tube could be detected by the BPM pickups and cause measurement issues. Therefore, an electron suppression ring will be placed between the BPM and the Beryllium window in order to avoid any interactions.

The electronics used to measure the beam position will also require a custom design. The plan is to process the data for each pulse to provide several position measurements along the 450 μs pulse length, thus providing the capability to measure the position as the beam is rastering. The BPM electronics will use the calculated position data to determine if the beam is rastering as expected, and if not, issue a signal to the beam interlock system to inhibit the beam.

Beam Current Transformers

The AC Current Transformer (ACCT) beam line devices (2) and associated processing electronics and cables will be purchased from Bergoz Instrumentation. Two identical systems will be provided to ensure reliability.
The ACCT is a non-interceptive current transformer. The sensor is built with a single winding, which requires only one wire pair between sensor and electronics; this allows much better EMI rejection when long cables are used. The electronics circuit is multistage, implementing the best low-noise operational amplifier available for this application. The ACCT chosen for the BLIP Raster project consists of an in-flange version of the toroid sensor embedded in a 10" OD CF flange. The in-flange version was chosen to eliminate the need to design a custom mechanical image-bypass shroud and enclosure.
The matched signal processing active electronics circuit is provided in a small box. The full-scale range for ±1 V output can be set for ±100 mA of beam current (BLIP design is 50mA). The system frequency response (-3dB) is from <5 Hz to 200 kHz and the rms noise is specified at 5 mV pp. The cable from toroid sensor to electronics box can be up to 100 m long; this enables the electronics to be mounted outside the beam line enclosure. The measured current signal will be digitized by a scope or VME digitizer and available remotely via the Controls system. A ten turn calibration winding option will be included; it will be driven by a commercial calibration current source to ensure the accuracy of the measurement.
A backscatter shield will be placed between the beryllium window and the current transformers for protection from neutrons.

View Port for Future Beam Density Profile

A viewport will be placed on the beam line in order to view the beryllium window. The 45° viewport will allow for taking density profile measurements from the upstream side in the future. The camera and associated equipment will not be installed at this time.

Beam Interlock System

The purpose of the beam interlock system is to inhibit beam to the BLIP beam line when the beam is not rastering as expected. The beam interlock system is critical because BLIP targets can be destroyed if high intensity beam hits the target in the same spot for the entire pulse length for more than a few consecutive cycles.

Several types of problems can prevent the beam from rastering as expected, including:

1. Raster power supply failure
2. Magnet failure
3. Incorrect function driving power supply

Custom electronic hardware will be developed to provide the required functionality. Redundant interlocks will be employed to determine that beam is rastering as expected.

The primary interlock method involves digitizing and monitoring the raster power supply current and aligning this signal with the beam current transformer signal to confirm that the power supply current is modulating when the beam passes through the magnet. However, since the continuous raster power supply option will likely be selected, using the current transformer signal may not be necessary. An additional method of interlock may use the BPM measurement system as described above. In the operational case where beam rastering is not desired, the interlock system must provide an option to allow non-rastered beam if the beam current is below a configurable threshold.
Another possibility for raster detection is to use a signal from the laser profile monitor. Specific details for this option require additional research and consideration.

A hardware output signal will be generated and connected to the existing Linac beam inhibit system to prevent beam from entering the BLIP line when the raster system is not operating as expected.

Work Breakdown Structure (WBS) with Costs

1.0		**Raster AIP**	
1.1		Management	266
1.2		Construction	2888
	1.2.1	Instrumentation	1932
	1.2.2	Magnet and Vacuum	646
	1.2.3	Power Supplies	311
1.3		Installation	511
1.4		Commissioning	82
1.5		Project Milestones (high level)	0
		Subtotal	3747
		Contingency	753
		Total	4500

Cost and Schedule

The Total Project Cost is $4.5M in AY dollars, funded by Accelerator Improvement Project (AIP) funds. It is planned that $3.6M is received in FY2014 and $0.9M in FY2015. This includes $753k (20%) of project contingency funds.

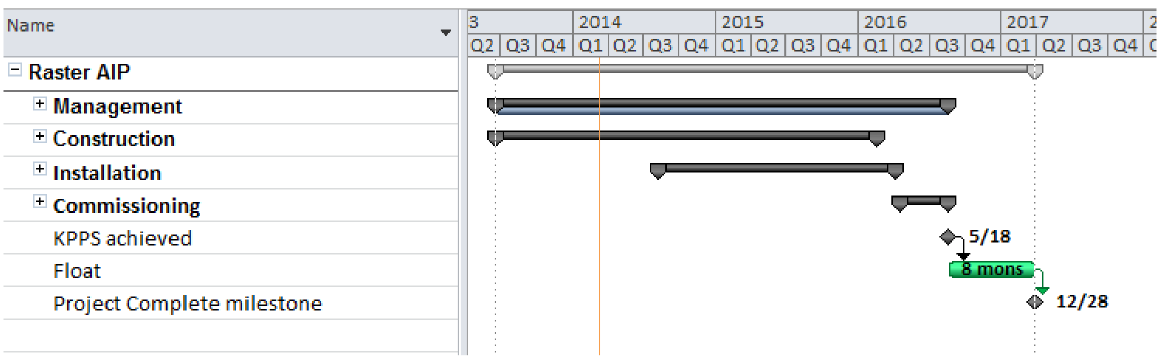
Subsystem experts for each WBS generated the cost estimates, and it is planned that the same individuals will be the System Lead for the BLIP Raster design, fabrication and installation. Most of the material dollars estimated at this pre-design phase are historical costs, catalog pricing and engineering judgment. Contingency was applied at each task line, and the resulting average contingency is 20%, or $753k for the total project.

Project Management of the AIP has been estimated as level of effort. The Contractor Project Manager, Rob Michnoff and Project Controls Manager Kerry Mirabella are each estimated at ~20% of their time. The Project Manager is also the subsystem manager for Raster Instrumentation, and his total time on the project is estimated at 40-50%.

A resource-loaded schedule has been developed in Microsoft Project and includes subsystem milestones as well as high-level Project milestones. The schedule assumes that purchasing of components and some equipment will begin in January 2014. All Raster equipment will be installed by November 2015 with commissioning starting immediately following the Site Office Approval to Operate.

The schedule contains 7.5 months of float from the planned completion to the Project Complete milestone date. In addition, no labor resources are assumed to be available 100% of the time. As an example, the estimated engineering hours are 6028, which could be accomplished by the 16 engineers identified for the project in less than 3 months if they were assigned fulltime. Instead their scope has been scheduled with lag times and will be accomplished in 31 months (planned Early Finish date).

High Level Schedule



Please note that the scheduling software has rounded the schedule float to 8 months, from 7.5.

Funding profile

The funding profile assumes a continuing resolution in FY15; therefore the funds requested for FY14 cover the first 5 quarters of planned costs to avoid impact to project progress.

FY14 - $3600k
FY15 - $ 900k

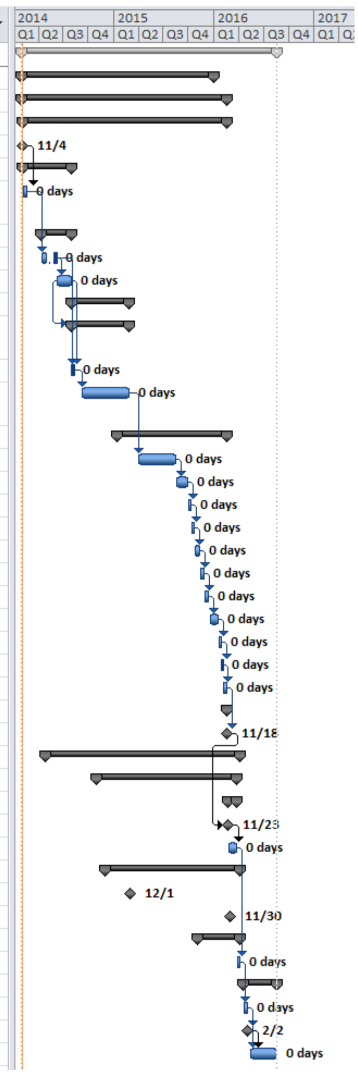
Cost Profile

Raster Cost plan ($k, with contingency applied)						
1QFY14	**2QFY14**	**3QFY14**	**4QFY14**	**FY15**	**FY16**	**Total**
342	1115	938	560	1363	182	4500

Critical Path

The current critical path within the project's Early Finish schedule is power supply fabrication, test and installation.

WBS	Task Name	Start	Finish
1.	**Raster AIP**	**Fri 11/1/13**	**Wed 5/18/16**
1.1	**Management**	**Fri 11/1/13**	**Wed 9/30/15**
1.2	**Construction**	**Fri 11/1/13**	**Fri 11/20/15**
1.2.3	**Power Supplies Construction**	**Mon 11/4/13**	**Fri 11/20/15**
1.2.3.1	Power Supplies Construction Start Milestone	Mon 11/4/13	Mon 11/4/13
1.2.3.2	**Design**	**Mon 11/4/13**	**Wed 4/30/14**
1.2.3.2.1	Physics parameter specification and option evaluation	Mon 11/4/13	Mon 11/18/13
1.2.3.2.2	**Raster Scanner PS Design**	**Thu 1/9/14**	**Wed 4/30/14**
1.2.3.2.2.1	Prototype Continuous Generator Design	Thu 1/9/14	Wed 3/5/14
1.2.3.2.2.2	High level design (Capacitors)	Wed 3/5/14	Wed 4/30/14
1.2.3.3	**Procurement**	**Wed 4/30/14**	**Wed 11/26/14**
1.2.3.3.1	**High level components specification and procurements**	**Wed 4/30/14**	**Wed 11/26/14**
1.2.3.3.1.1	Vendor Requisition and Support	Wed 4/30/14	Wed 5/7/14
1.2.3.3.1.3	HVPS, cable, connector, racks and other HV components specification and procurements	Thu 6/5/14	Wed 11/26/14
1.2.3.4	**Assembly & Test**	**Tue 10/14/14**	**Wed 11/18/15**
1.2.3.4.3	Production units high level assembly	Mon 12/29/14	Fri 5/15/15
1.2.3.4.4	High level test	Fri 5/15/15	Tue 6/30/15
1.2.3.4.9	System set I integration	Tue 6/30/15	Thu 7/9/15
1.2.3.4.10	System set I test with magnet or dummy load	Thu 7/9/15	Thu 7/23/15
1.2.3.4.11	Set I Modification	Thu 7/23/15	Thu 8/13/15
1.2.3.4.12	Set I Retest	Thu 8/13/15	Thu 8/27/15
1.2.3.4.13	Design modification and documentation	Thu 8/27/15	Fri 9/11/15
1.2.3.4.14	Low level system set II assembly	Fri 9/18/15	Fri 10/16/15
1.2.3.4.15	Low level system set II test with magnet	Fri 10/16/15	Fri 10/30/15
1.2.3.4.16	System set II integration	Fri 10/30/15	Tue 11/3/15
1.2.3.4.17	System set II test	Tue 11/3/15	Wed 11/18/15
1.2.3.5	**Documentation**	**Wed 11/18/15**	**Fri 11/20/15**
1.2.3.5.3	Raster Scanner PS Available for Installation Milestone	Wed 11/18/15	Wed 11/18/15
1.3	**Installation**	**Mon 1/27/14**	**Mon 1/4/16**
1.3.4	**Phase 1 Installation Outside BLIP Tunnel**	**Fri 8/1/14**	**Wed 12/23/15**
1.3.4.4	**Power Supplies Installation**	**Mon 11/23/15**	**Wed 12/23/15**
1.3.4.4.1	Raster Scanner PS Available for Installation	Mon 11/23/15	Mon 11/23/15
1.3.4.4.2	Rack , integrate and power (Power Supplies)	Mon 11/23/15	Wed 12/23/15
1.3.5	**Phase 2 Installation Inside BLIP Tunnel**	**Tue 9/2/14**	**Mon 1/4/16**
1.3.5.2	2014 Installation Finish Milestone	Mon 12/1/14	Mon 12/1/14
1.3.5.4	2015 Installation Finish Milestone	Mon 11/30/15	Mon 11/30/15
1.3.5.12	**Install Subsystems and Collateral Support Systems**	**Mon 8/3/15**	**Mon 1/4/16**
1.3.5.12.7	Magnet Testing in Tunnel	Wed 12/23/15	Mon 1/4/16
1.4	**Commissioning**	**Tue 1/19/16**	**Wed 5/18/16**
1.4.1	Test Raster System without Beam	Tue 1/19/16	Tue 2/2/16
1.4.2	Start Run without Raster System	Tue 2/2/16	Tue 2/2/16
1.4.3	Turn Raster System On and Commission System with Beam	Tue 2/9/16	Wed 5/18/16



Milestones

The chart below shows the milestones for reporting purposes. There are 7.5 months of schedule float from the planned early finish completion to the Project Complete Milestone.

Reporting Milestones	date
Project Start	Nov 4 2013 (A)
Designers assigned to project	1QFY14 (A)
Access BLIP Spur	1QFY14 (A)
PM trip to LANL	2QFY14
Current Transformers ordered	2QFY14
Material ordered for Plunging Multiwire Profile monitor	2QFY14
Decision on Rad Hard vs. periodic replacement	3QFY14
Design Review & Accelerator Systems Safety Review	4QFY14
Summer/Fall 2014 access to BLIP Tunnel	1QFY15
All power supply purchases received	2QFY15
Vacuum fabrication begins	3QFY15
Magnet stand fabrication begins	3QFY15
Vacuum Chamber bakeout	4QFY15
Summer/Fall 2015 access for BLIP Tunnel Installation	4QFY15
Raster magnet available for installation	1QFY16
Plunging Multiwire Profile Monitor available for installation	1QFY16
Accelerator Systems Safety Review-installed	1QFY16
Power supply installation	2QFY16
DOE approval to operate	2QFY16
Begin Raster System test without beam	3QFY16
Confirmation of Rastering	4QFY16
Project complete	1QFY17

Risk

The attached Risk list and mitigations were developed by the system experts using the guidelines in the Raster Project Risk Management Plan and will be revised monthly as needed, once funding is received.

	WBS	Description	Type of Risk	Consequence	Likeli-hood	Cost Impact (burdened $k)	Risk Expiration	Mitigation Plan	Notes
		BNL Raster AIP Risk List							
High Risk									
Medium Risk	**1.0**	Availability of personnel and other resources	Schedule	Level2	Likely		1QFY16	Use of overtime, contract labor	after funding is received and a start date is known, begin redefining near term resources with individual names (where possible) and forward to individuals and their supervisors.
	1.0	The tunnel in the area where this equipment will be installed is a high radiation area. Damage to equipment may occur, including the laser for the laser profile monitor, motors and other mechanical devices, cables, connectors, etc.	Cost	Level2	Likely		3QFY14	Engineering time is included for consideration of high radiation issues.	radiation-hardened devices vs. periodic replacement of equipment that is expected to fail due to high radiation. As part of the design process, equipment testing must be performed in the high radiation environment to study potential failure modes. For example, motor controls and fiber optic cables can be installed in the BLIP tunnel to test the radiation effects. Consider design for laser transport system to minimize radiation exposure - shielding, locating laser outside tunnel, etc.
	1.2.1	Beam position monitor system not capable of measuring BLIP beam, which is mostly debunched by the time it reaches the BLIP beamline.	Technical	Level1	Unlikely		1QFY15	Engineering development includes 30% contingency to account for design uncertaity.	Testing revealed that a stripline BPM typical of that installed in the linac does not produce a measureable signal with the nearly debunched BLIP beam. This is because the llast accelerating RF tank for the BLIP beam is tank 5 (of 9), which is a long distance from the BLIP beam line. An alternative BPM device will be required, possibly requiring signficant R&D work. In addition, the Beam Position Monitor electronics must be capable of measuring beam motion while rastering over the 450 microsecond bunch length. The 200 MHz beam structure and possible low signal levels presents technical challenges.
	1.3	The high radiation environment of the BLIP tunnel coupled with a changeable and short (~3-4 months) access period will make installation scheduling challenging.	Schedule	Level 2	Likely		1QFY17	Initally plan for 3 Installation opportunities over 3 years. Add tasks (and dates) to the schedule to define equipment and material at subsystem level which will be installed in the BLIP Control Room. Develop a detailed tunnel installation schedule approximately 3 months before each tunnel access period.	Items will be installed in 2 locations; the BLIP tunnel, and its Control Room. Cables running from one to the other will connect some equipment. BLIP typically stops running in June or July, access is permitted 4 weeks after that to allow radiation levels to decrease. BLIP start up can occur in Dec or January. Access to the tunnel is not permitted when the Linac runs beam for NSRL (NASA Space Radiation Laboratory), normally for 2-3 weeks each fall.
Low Risk	**1.0**	Electronic signal measurements are hampered by EMI noise.	Technical	Level3	Likely		3QFY15	Engineering time is included for consideration of EMI issues.	Good signal noise reduction techniques will be essential in the electronic design.
	1.2.1	Malfunction of interlock system could cause BLIP target damage if system does not raster beam as expected.	Technical, Cost	Level2	Unlikely		4QFY15	A robust interlock system must be designed, and is included as part of this proposal.	The interlock system must inhibit beam to the BLIP target if the beam is not rastering. Confirmation that the system is rastering as expected will require monitoring a combination of signals including beam current transformer, power supply currents, beam position monitor and laser profile monitor. Options for robust operation require significant consideration.
	1.2.2	Ceramic beam tube fabrication for raster magnet	Cost, Schedule	Level2	Unlikely		1QFY15	Choose experienced vendor, optimize design based on vendor's experience, order a spare.	Choose experienced vendor, optimize design based on vendor's experience, order a spare.
	1.2.1	The Laser Profile Monitor can not scan the beam while the beam is rastering.	Technical	Level3	Unlikely		1QFY15	Engineering development time is included for this requirement. 30% contingency is included to account for design uncertainty.	Determine effects of beam movement on the measurement. Determine if the laser can be scanned quickly to provide several measurements during one 450 microsecond bunch, and/or if averaging can be used to provide a profile of the full beam raster motion.
	1.2.1	Locating electronic equipment outside the tunnel (to avoid radiation damage) may require fairly long cable lengths. Signal integrity with long cable lengths may be an issue.	Technical	Level3	Likely		3QFY14	Contingency is included to consider signal integrity issues.	The design must weigh the sacrifices between installing electronics in the tunnel and risking potential damage due to radiation, and signal integrity issues due to processing low level signals with long cable lengths.
	1.0	Availability of penetrations and adequate radiation shielding from tunnel to BLIP control room.	Cost	Level3	Likely	$100,000	4QFY14	Contingency is included in case more work than anticipated is required to provide penetrations and adequate radiation shielding.	Penetrations appear to be available from the BLIP control room where the racks will be located to the tunnel below. Specific radiation shielding requirements have not yet been fully studied.

Instrumentation Systems performance

The following table defines early and enhanced performance for each of the instrumentation systems. The early performance column lists the minimum functionality required to achieve the UPPs, and the enhanced performance column lists additional future functionality goals that will improve operational reliability and effectiveness. All the instrumentation systems combined provide for some redundancy and therefore operational robustness.

System	Early Performance	Enhanced Performance
Plunging Multiwire	Basic profile data available, plunge and acquire profile on request	Improved integration into control system, including application development if required.
Beam Interlock System	Inhibit LINAC beam if the power supply current does not show 5 kHz motion and the beam current is above a configured threshold.	Use beam position monitor measurements as additional method for determining that the system is rastering as expected. Inhibit LINAC beam if any signal indicates that the beam is not rastering as expected.
Beam Current Transformer	Continuous current measurements available, signal used for beam interlock	
Laser Profile Monitor	Semi-manual scanning of laser, study operational modes (constant laser position for each 450 microsecond pulse vs. laser sweep during 450 microsecond pulse, etc.)	Automated profile scanning, data delivery and logging to higher level control system; position feedback using profile data
Beam Position Monitor	Limited position data available. Measure the position at the beginning and end of each pulse.	Provide many position measurements during each pulse (possibly at 50 kHz rate or faster) to create sufficient plots for monitoring raster motion; incorporate measurements into beam interlock system; develop software application if required.